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An international literature survey on energy-economic growth nexus: Evidence from country-specific studies

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ABSTRACT

In this paper, an extensive review of the rapidly growing in the literature on the nexus between economic growth and four types of energy consumption: total energy consumption, electricity consumption, nuclear consumption, and renewable consumption. The various hypotheses associated with the causal interaction between these variables along with a survey of the empirical literature are also discussed. The survey focuses on country coverage, periods, modeling techniques, and empirical conclusions. A general observation from these studies that results are found to be sensitive to methodology and type of energy considered. The empirical results for the specific countries surveyed show that (i) for energy consumption-growth nexus: 29% supported the growth hypothesis, 27% the feedback hypothesis, 23% the conservation hypothesis, and 21% the neutrality hypothesis; (ii) for the electricity consumption-growth nexus: 40% supported the growth hypothesis, 33% the feedback hypothesis, and 27% conservation hypothesis; (iii) for the nuclear consumption-growth nexus: 60% supported the neutrality hypothesis, and 40% the growth hypothesis; and (iv) for the renewable consumption-growth nexus: 40% supported the neutrality hypothesis, 40% the conservation hypothesis, and 20% the growth hypothesis. These mixed results may be attributed to the different used data, selected variables, and econometric approaches undertaken.

Contents

1. Introduction

After more than three decades empirical research has not yielded a consensus on the causal relation between energy consumption and economic growth. More recently, the subject has garnered attention due to rising energy costs along with the desire to reduce greenhouse gas emissions. Various studies have focused on different countries, time periods, modeling techniques and different proxy variables have been used for energy consumption and economic growth nexus. The empirical results of these studies are mixed and have not reached a consensus. The results differ even on the direction of causality and its long-term versus

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short-term effect on energy policy. The policy implications of these relationships can be significant depending upon what kind of causal links exists [14]. Indeed, understanding the two-way linkages between 'energy consumption and economic growth', 'electricity consumption and economic growth', 'nuclear consumption and economic growth' and 'renewable consumption and economic growth' are important in the design and implementation of environmental and energy policies.

The mixture and the inconclusivity of the previous results are due to the different countries' characteristics, different dataset, and alternative econometric methodology. The difference in countries' characteristics include the different indigenous energy supplies, political and institutional arrangements, energy policies, political and economic histories, and cultures, etc. Chen et al., (2007) [19].

The literature on the causal link among energy type variables (energy consumption, electricity consumption, nuclear consumption, and renewable consumption) and economic growth could be synthesized into four testable hypothesis: feedback, growth, conservation, and neutrality hypothesis hypotheses ([19,77,10]; and [62]). First, the *feedback hypothesis* suggests that there is a bidirectional causality relationship among energy consumption and economic growth. It implies that energy consumption and economic growth are interrelated and may very well serve as complements to each other [77]. Second, the *growth hypothesis* suggests that there is unidirectional causal relationship running from energy consumption to economic growth. It implies that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to labor and capital. So, we may conclude that energy is a limiting factor to economic growth and, hence, shocks to energy supply will have a negative affect on economic growth [10,62]. Third, the *conservation hypothesis* supports that there is unidirectional causality running from economic growth to energy consumption. It implies that an increase in economic growth increases the consumption of energy. Nevertheless, it is possible that a growing economy constrained by infrastructure or mismanagement of resources could produce inefficiencies and the reduction in the demand for goods and services, including energy consumption [77]. If this is the case, an increase in economic growth would have an adverse effect on energy consumption [10]. Finally, the *neutrality hypothesis* suggests the no causality among economic growth and energy consumption. This hypothesis considers energy consumption to be a small component of overall economic growth and thus have little or no effect on economic growth. It indicates that neither conservative nor expansive policies in relation to energy consumption have no impact on economic growth.

The existing energy economics literature provides two survey studies by Payne [65] reviewing electricty-growth nexus as well as energy-growth nexus. Ozturk, [62] surveyed studies on electricty-growth and energy-growth. We have extended the survey by incorporating nexus between renewable energy-growth as well as nuclear energy-growth nexus.[1] In light of the above mentioned hypothesis, the objective of this study is to provide a survey of the international studies on the causality between energy consumption (electricity, nuclear, and renewable consumption) and economic growth for a period of 1978 to 2012. To the best of our knowledge, this is the first study that surveys and discusses at the same time the causal relationship between four energy type variables and economic growth each of which nexus has important recommendations for energy policy. The plan of this study is organized as follows: after the introduction, which is presented in Section 1 above, we move to Section 2 to review and analyze the literature for county-specific studies on the causality between energy consumption-economic growth, electricity consumption-economic growth, nuclear consumption-economic growth, and renewable consumption-economic growth. The concluding remarks are given in the third section.

[1] We have also inserted some recent studies publsihed on electrcity-growth nexus as well as on energy-growth nexus.

2. Energy-growth nexus: a literature survey

After the pioneer seminal study of Kraft and Kraft [44], who examined the causal relathionship between energy consumption and economic growth for United States, several studies have attempted to establish the nexus among diferent energy variables and economic growth by employing different econometric methodologies. Therefore, we analyze, in this section, these issues by given chronological lists of the existing empirical studies classified by author, country, period, methodology, and results (Tables 1–4).[2]

2.1. Literature survey on the causality between energy consumption and economic growth

The analyzes of country-specific causality studies among energy consumption and economic growth is important to design an environmental and energy policies that will promote sustainable development. Policy makers need to know this interaction and which additional variables lead economic growth in order to manage tools such as rationing energy consumption and controlling environmental degradation. Hence, several empirical studies have attempted to establish this nexus and their results are not conclusive and mixed. The variation in results may be attributed to time periods, used variables, model specifications, and econometric methodologies undertaken. Accross different countries when time-series anlysis is applied to an individual country dataset as shown in Table 1.

The findings of the recent empirical studies on the causal links between energy consumption and economic growth for country-specific studies are summarized in Table 1. In most of the empirical studies undertaken in our survey, bi-variate models are used to investigate the causal links between energy consumption and economic growth. However, only in few studies, multivariate models are also used to examine this nexus. Beside to GDP and energy consumption variables in the bi-variate models, capital, labor, and CO_2 emissions variables are incorporated in the multivariate models. Bartleet and Gounder [13] for New Zealand, Wang et al. [84] and Zhixin and Xin [103] for China, among others, are good examples in which the multivariate framework is used by incorporating capital stock and labor force variables to examine the direction of causality between energy consumption and economic growth.

A general conclusion from these studies reported in Table 1 is that, with respect to the conclusions pertaining to the growth, conservation, neutrality, and feedback hypotheses, the results are indeed mixed across the 48 studies reported. The results for each hypothesis are given by percentage in Fig. 1. The results for surveyed studies show that 29% supported the growth hypothesis; 27% the feedback hypothesis; 23% the conservation hypothesis; and 21% the neutrality hypothesis. Given that nearly 56% of the specific countries surveyed provide support for either the feedback or growth

[2] Every attempt was made to include all the studies published in refereed academic journals that examine the causality among four types of energy consumption and economic growth. If a study has been overlooked or misinterpreted, I extend my apologies to the author(s).

Table 1
Summary of empirical studies on energy consumption-growth nexus.

No.	Author(s)	Countries	Period	Methodology	Conclusion (s)			
					$EC \rightarrow Y$	$Y \rightarrow EC$	$Y \leftrightarrow EC$	$Y \neq EC$
1.	Kraft and Kraft [44]	USA	1947–1974	Granger causality		X		
2.	Akarca and Long [4]	USA	1950–1970	Sim's technique				X
3.	Yu and Hwang [95]	USA	1947–1979	Sim's technique				X
4.	Abosedra and Baghestani [1]	USA	1947–1187	Cointegration, Granger causality		X		
5.	Hwang and Gum [38]	Taiwan	1961–1990	Cointegration, ECM			X	
6.	Yu and Jin [96]	USA	1974–1990	Cointegration, Granger causality				X
7.	Stern [78]	USA	1947–1990	Multivariate VAR model	X			
8.	Cheng [20]	USA	1947–1990	Cointegration, Granger causality				X
9.	Cheng and Lai [21]	Taiwan	1954–1993	Granger causality		X		
10	Glasure, Lee [32]	Korea	1961–1990	Hsiao's Granger causality			X	
11.	Cheng [22]	Japan	1952–1995	Hsiao's Granger causality		X		
12.	Cheng [23]	India	1952–1995	Cointegration, ECM Granger causality		X		
13.	Stern [79]	USA	1948–1994	Cointegration, Granger causality	X			
14.	Soytas et al. [76]	Turkey	1960–1995	Cointegration, Granger causality	X			
15.	Aqeel and Butt [11]	Pakistan	1955–1996	Hsiao's version of Granger causality, Cointegration		X		
16.	Fatai et al. [27]	New Zealand	1960–1999	Granger causality, ARDL, Toda and Yamamoto test				X
17.	Hondroyiannis et al. [36]	Greece	1960–1996	Cointegration, ECM, Variance decomposition			X	
18.	Altinay and Karagol [7]	Turkey	1950–2000	ECM				X
19.	Ghali and El-Sakka [28]	Canada	1961–1997	Hsiao's version of Granger causality			X	
20.	Oh and Lee [61]	Korea	1970–1999	Cointegration, Granger causality			X	
21.	Paul and Bhattacharya [68]	India	1950–1996	Granger causality, ECM	X			
22.	Wolde-Rufael [85]	Shanghai	1952–1999	A modified version of Granger causality	X			
23.	Lee and Chang [46]	Taiwan	1954–2003	Johansen–Juselius, Cointegration, VECM	X			
24.	Ang [8]	France	1960–2000	Cointegration, VECM	X			
25.	Lee and Chang [47]	Taiwan	1955–2003	Granger causality, Cointegration, VECM	X			
26.	Jobert and Karanfil [40]	Turkey	1960–2003	Granger causality				X
27.	Ho and Siu [35]	Hong Kong	1966–2002	Cointegration, VECM	X			
28.	Zamani [100]	Iran	1967–2003	Granger causality, Cointegration, VECM		X		
29.	Lise and Van Montfort [50]	Turkey	1970–2003	Cointegration		X		
30.	Ang [9]	Malaysia	1971–1999	Johansen cointegration, VECM		X		
31.	Erdal et al. [25]	Turkey	1970–2006	Pair-wise Granger causality, Johansen cointegration			X	
32.	Bowden and Payne [15]	USA	1949–2006	Toda–Yamamoto causality test	X			
33.	Halicioglu [34]	Turkey	1960–2005	Granger causality, ARDL, Cointegration				X
34.	Payne [64]	USA	1949–2005	Toda–Yamamoto causality test				X
35.	Soytas and Sari [75]	Turkey	1960–2000	Toda–Yamamoto causality test				X
36.	Belloumi [14]	Tunisia	1971–2004	Granger causality, VECM			X	
37.	Odhiambo [59]	Tanzania	1971–2006	ARDL bonds test; Granger causality-VECM	X			
38.	Zhang and Cheng [101]	China	1960–2007	Granger causality		X		
49.	Bartleet and Gounder [13]	New Zealand	1960–2004	Granger causality		X		
40.	Chang [18]	China	1981–2006	Multivariate causality test based on VECM	X			
41.	Mandal and Madheswaran [52]	India	1979–2005	Cointegration, ECM			X	
42.	Tsani [82]	Greece	1960–2006	Toda–Yamamoto causality test			X	
43.	Wang et al. [83]	China	1995–2007	Cointegration, VECM			X	
44.	Wang et al. [84]	China	1972–2006	Cointegration, ARDL	X			
45.	Zhang [102]	Russia	1970–2008	Cointegration, Granger causality			X	
46.	Zhixin and Xin [103]	China	1980–2008	Cointegration, Granger causality			X	
47.	Alam et al. [6]	Bangladesh	1972–2006	Johansen–Juselius, Cointegration, VECM	X			
48.	Dagher and Yacoubian [24]	Lebanon	1980–2009	Hsiao's Granger causality, Toda-Yamamoto, VECM			X	

Notes: $EC \rightarrow Y$, $Y \rightarrow EC$, $Y \leftrightarrow EC$, and $Y \neq EC$ indicate the unidirectional causality running from energy consumption to economic growth, from ecnomic grwth to energy consumption, feedback hypothesis and neutral hypothesis between energy consumption and economic growth, respectively.

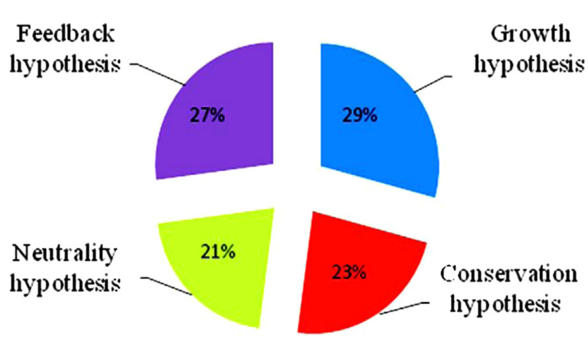


Fig. 1. Hypotheses for energy-growth nexus (in %).

hypotheses indicates that energy conservation policies that adversely impact on energy consumption may have an adverse effect on economic growth. These difference in results may arise due to the varying energy consumption and economic growth measures, the econometric techniques, the presence of omitted variable bias, and the time horizons of the studies undertaken.

In addition to the studies reported in Table 1 on the causal relationships among energy consumption and economic growth, there are some other energy-growth nexus studies such as Fallahi [26] and Li et al. [49], which employ different techniques and examine the different aspects of energy-growth nexus. These studies are summarized below.

Fallahi [26] examines the inter-temporal link between energy consumption and Gross Domestic Product (GDP) in the United States by using Markov-switching vector autoregressive (MS-VAR) models. The results show the evidence of bidirectional Granger causality between the variables in the first regime, while there is no Granger causality between the variables in the second regime. For a sample of 30 provinces in China from 1985 to 2007, Li et al. [49] reinvestigate the relationship among energy consumption

Table 2
Summary of empirical studies on electricity-growth nexus.

No.	Author(s)	Countries	Period	Methodology	Conclusion (s)			
					ELC→Y	Y→ELC	Y↔E	Y≠ELC
1.	Ramcharran [69]	Jamaica	1970–1986	Granger causality	X			
2.	Yang [89]	Taiwan	1954–1997	Granger causality, Hsiaao's Granger			X	
3.	Ghosh [29]	India	1950–1997	Granger causality		X		
4.	Jumbe [41]	Malawi	1970–1999	Granger causality, ECM			X	
5.	Shiu and Lam [74]	China	1971–2000	Cointegration, ECM		X		
6.	Altinay and Karagol [7]	Turkey	1950–2000	Granger causalityn, Dolado-Lutkepohl test	X			
7.	Yoo [91]	Korea	1970–2002	ECM (Error Correction Model)			X	
8.	Narayan and Smyth [56]	Australia	1966–1999	Multivariate Granger causality		X		
9.	Yoo and Kim [92]	Indonesia	1971–2002	Engle Granger, VAR		X		
10.	Zachariadis and Pashouortidou [99]	Cyprus	1960–2004	Cointegration, Granger causality, VEC			X	
11.	Mozumder Marathe [55]	Bangladeh	1971–1999	Cointegration, VECM		X		
12.	Ho and Siu [35]	Hong Kong	1966–2002	Cointegration, VECM	X			
13.	Yuan et al. [97]	China	1978–2004	Cointegration	X			
14.	Narayan and Singh [57]	Fiji Islands	1971–2002	Cointegration, Granger causality	X			
15.	Halicioglu [33]	Turkey	1968–2005	Granger causality		X		
16.	Hu and Lin [37]	Taiwan	1982–2006	Hansen-Seo threshold cointegration, VEC		X		
17.	Aqeel and Butt [12]	Pakistan	1955–1996	Engle Granger, VAR	X			
18.	Yuan et al. [98]	China	1963–2005	Johansen cointegration, VEC	X			
19.	Abosedra et al. [2]	Lebanon	1995–2005	Granger cauality	X			
20.	Akinlo [5]	Nigeria	1980–2006	Johansen-Juselius, cointegration, VEC	X			
21.	Bowden and Payne [15]	USA	1949–2006	Toda–Yamamoto causality test	X			
22.	Odhiambo [59]	Tanzania	1971–2006	ARDL bonds test; Granger causality-VECM	X			
23.	Odhiambo [60]	South Africa	1971–2006	Granger causality			X	
24.	Tang [81]	Malaysia	1970–2005	ARDL bonds test; Granger causality			X	
25.	Zhang and Cheng [101]	China	1960–2007	Granger causality		X		
26.	Acaravci [3]	Turkey	1968–2005	Cointegration, VECM			X	
27.	Chandran et al. [17]	Malaysia	1971–2003	ARDL bonds test	X			
28.	Ighodaro [39]	Nigeria	1970–2005	Cointegration, Granger causality	X			
29.	Lorde et al. [51]	Barbados	1960–2004	VAR models, Granger causality			X	
30	Shahbaz et al. [71]	Portugal	1971–2009	ARDL bonds test; UECM			X	
31.	Alam et al. [6]	Bangladesh	1972–2006	Johansen-Juselius, Cointegration, VECM			X	
32.	Shahbaz and Feridun [72]	Pakistan	1971–2008	ARDL bonds test		X		
33.	Shahbaz and Lean [73]	Pakistan	1972–2009	Cointegration, Granger causality			X	

Notes: ELC→Y, Y→ELC, Y↔ELC and Y≠ELC indicate the unidirectional causality running from electricty consumption to economic growth, from ecnomic grwth to electricty consumption, feedback hypothesis and neutral hypothesis between electricty consumption and economic growth, respectively.

and economic growth by using panel unit root and panel cointegration. They show that there is a positive long-run cointegrated relationship among energy consumption and economic growth variables. Furthermore, they investigate two cross-regional groups, namely the east China and west China groups, and get more important results and implications. In the long-term, a 1% rise in economic growth raises energy consumption by approximately 0.48–0.50% and accordingly raises the CO_2 emissions by about 0.41–0.43% in China.

Overall results from the reviewed studies in this subsection show that the litearure on energy consumption-growth nexus produced inconclusive results and their is no consensus neither on the existence nor on the direction of causality among energy consumption and economic growth.

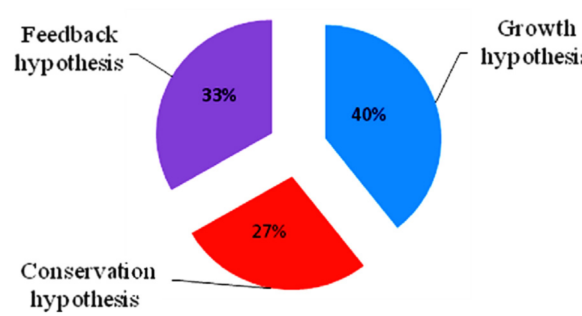


Fig. 2. Hypotheses for electricity-growth nexus (in %).

2.2. Literature survey on the causality between electricity consumption and economic growth

In this subsection, we analyze the causal relationship among electricity consumption and economic growth by given, in Table 2, a chronological lists of the existing empirical studies classified by author, country, period, methodology, and conclusions.

A general conclusion from these studies reported in Table 2 is that, with respect to the conclusions pertaining to the growth, conservation, neutrality, and feedback hypotheses, the results are indeed mixed across the 33 studies reported. The results for each hypothesis are given by percentage in Fig. 2. The results for surveyed studies show that 40% supported the growth hypothesis; 33% the feedback hypothesis; and 27% the conservation. Given that nearly 77% of the specific countries surveyed provide support for either the feedback or growth hypotheses indicates that energy conservation policies that adversely impact on electricity consumption may have an adverse effect on economic growth. These difference in results may arise due to the varying electricity consumption and economic growth measures, the econometric techniques, and the time horizons of the studies undertaken.

In addition to the studies reported in Table 2 on the causal relationship between electricity consumption and economic growth, there are some other studies on electricity-growth nexus such as Tang [80], Ghosh [30], [45], Kouakou [43] and Abdullah et al. (2013) that employ different techniques and examine the different aspects of electricity-growth nexus. These studies are summarized below.

Table 3
Summary of empirical studies on nuclear-growth nexus.

No.	Author(s)	Country	Period	Methodology	Conclusion (s)			
					NE→Y	Y→NE	Y↔NE	Y≠NE
1.	Yoo and Jung [93]	Korea	1972–2002	VECM	X			
2.	Payne and Taylor [66]	USA	1957–2006	Toda–Yamamoto causality test				X
3.	Menyah and Wolde-Rufael [53]	USA	1960–2007	Toda–Yamamoto causality test				X
4.	Wolde-Rufael [86]	India	1969–2006	Toda–Yamamoto causality test	X			
5.	Wolde-Rufael [88]	Taiwan	1977–2007	Toda–Yamamoto's Granger causality				X

Notes: NE →Y, Y→NE, Y↔ NE and Y≠NE indicate the unidirectional causality running from nuclear energy consumption to economic growth, from ecnomic grwth to nuclear energy consumption, feedback hypothesis and neutral hypothesis between nuclear energy consumption and economic growth, respectively.

Tang [80] re-investigates the causal relationship between electricity consumption and economic growth in Malaysia from 1972:1 to 2003:4. In this study, author adopted the newly developed ECM based F-test for cointegration to examine the presence of the long run equilibrium relationship by applying the autoregressive distributed lag (ARDL) model. The empirical evidence suggests that electricity consumption and economic growth are not cointegrated in Malaysia. However, standard Granger's test and MWALD test suggest that electricity consumption and economic growth in Malaysia Granger causes each other. Ghosh [30] investigates the causal links among electricity supply, employment and real GDP for India within a multivariate framework using autoregressive distributed lag (ARDL) bounds testing approach of cointegration. The long-run equilibrium relationship has been established among these variables for the time span 1970–71 to 2005–06. The study further establishes long-and-short runs Granger causality running from real GDP and electricity supply to employment without any feedback effect. Thus, growth in real GDP and electricity supply are responsible for the high level of employment in India. The absence of causality running from electricity supply to real GDP implies that electricity demand and supply measures can be adopted to reduce the wastage of electricity, which would not affect future economic growth in India. Chandran et al. [17] reinvestiagte the relationship between electricty consumption and ecnomic growth using electricty demand function in the case of Malaysisa. They applied the bounds testing and the VECM Granger causality for long run and causality relationship between the variables. Their analysis indicated that elasticity of electricity consumption on GDP is 0.7 and electricty consumption Granger cuases economic growth. Kouakou [43] examines the causal relationship between electric power industry and economic growth of Cote d'Ivoire. Using the data from 1971 to 2008, a test was conducted for the cointegration and Granger causality within an error correction model. The results from these tests reveal the bidirectional causality between per capita electricity consumption and per capita GDP. The unidirectional causality is found running from electricity consumption to industry value added appears in the short run. Economic growth is found to have great effect on electricity consumption and a reverse causality from electricity consumption to economic growth may also appear. In the long run, there is a unidirectional causality between electricity consumption and both GDP and industry value added. From these findings, the author concludes that the country will be energy dependent in the long run and must therefore secure the production network from shortfalls to ensure a sustainable development path. [4] employ annual data from 1971 to 2006 to examine the causal relationship between aggregate output, electricity consumption, exports, labor and capital in a multivariate model for Malaysia. They find that there is a bidirectional Granger causality running between aggregate output and electricity consumption. They also find support for the export-led hypothesis which states Granger causality runs from exports to aggregate output. This means that Malaysia is pursuing a successful export orientated strategy.

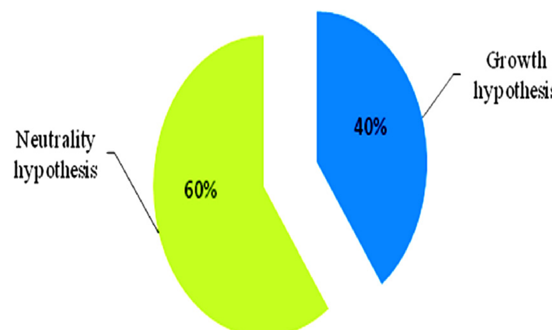


Fig. 3. Hypotheses for nuclear-growth nexus (in %).

Overall results from the reviewed studies in this subsection show that the litearure on electricity consumption-growth nexus produced inconclusive results and their is no consensus neither on the existence nor on the direction of causality among electricity consumption and economic growth.

2.3. Literature survey on the causality between nuclear consumption and economic growth

In this subsection, we herewith concentrate on analyzing the causal relationship among nuclear consumption and economic growth by presenting, in Table 3, a chronological lists of the existing empirical studies classified by author, country, period, methodology, and conclusions.

A general conclusion from these studies reported in Table 3 is that, with respect to the conclusions pertaining to the growth, conservation, neutrality, and feedback hypotheses, the results are indeed mixed across the 5 studies reported. The results for each hypothesis are given by percentage in Fig. 3. The results for surveyed studies show that 60% supported the neutrality hypothesis; and 40% the growth hypothesis. Given that nearly 60% of the specific countries surveyed provide support the neutrality hypotheses indicates that energy conservation policies do not affect income, and as such, energy conservation policies may be pursued without adversely affecting real income. These difference in results may arise due to the variables measures, the econometric techniques, and the time horizons of the studies undertaken.

In addition to the studies reported in Table 3 on the causal relationships between nuclear consumption and economic growth, there are some other nuclear-growth nexus studies, such as Yoo and Ku [94], Wolde–Rufael and Menyah [87], and Lee and Chiu [48], which employ different techniques and examine the

Table 4
Summary of empirical studies on renewable-growth nexus.

No.	Author(s)	Country	Period	Methodology	Conclusion (s)			
					NE→Y	Y→NE	Y↔NE	Y≠NE
1.	Sari et al. [70]	USA	1969–1999	ARDL bonds test		X		
2.	Payne [64]	USA	1949–2006	Toda–Yamamoto causality test				X
3.	Menyah and Wolde-Rufael [54]	USA	1960–2007	Granger causality		X		
4.	Payne [67]	USA	1949–2007	Toda–Yamamoto causality test	X			
5.	Yildirim et al. [90]	USA	1949–2010	Toda–Yamamoto causality test				X

Notes: NE →Y, Y→NE, Y↔ NE and Y≠NE indicate the unidirectional causality running from nuclear energy consumption to economic growth, from ecnomic grwth to nuclear energy consumption, feedback hypothesis and neutral hypothesis between nuclear energy consumption and economic growth, respectively.

different aspects of nuclear-growth nexus. These studies are summarized below.

Wolde–Rufael and Menyah [87] analyzed the direction of causality between nuclear energy consumption and economic growth in nine industrialized countries by using Toda–Yamanmoto causality test. They indicated the existence of the growth hypothesis for Japan, Netherlands, and Switzerland; the conservation hypothesis for Canada and Sweden; and the feedback hypothesis for France, Spain, the UK, and the USA. By employing the same method, Lee and Chiu [48] exmained the causal links between nuclear consumption and economic growth in six highly industrialized countries. Unlike Wolde–Rufael and Menyah [87], Lee and Chui (2011) supported the feedback hypothesis for Canada, Germany, and United Kingdom (UK); neutrality hypothesis for France and the USA; and conservation hypothesis for Japan. In an examination of the causality between nuclear energy consumption and economic growth for a sample of six countries, Yoo and Ku [94] supported the growth hypothesis for Korea; conservation hypothesis for France and Pakistan; feedback hypothesis for Switzerland; and neutrality hypothesis for Argentina and Germany.

Overall results from the reviewed studies in this subsection show that the litearure on nuclear consumption-growth nexus produced inconclusive results and their is no consensus neither on the existence nor on the direction of causality among nuclear energy consumption and economic growth.

2.4. Literature survey on the causality between renewable consumption and economic growth

In this subsection, we summarize and analyze the findings of the recent studies on the causal links between renewable energy consumption and economic growth. A general conclusion from these studies reported in Table 4 is that, with respect to the conclusions pertaining to the growth, conservation, neutrality, and feedback hypotheses, the results are indeed mixed across the 5 studies reported. The results for each hypothesis are given by percentage in Fig. 4. The results for surveyed studies show that 40% supported the neutrality hypothesis; 40% the conservation hypothesis; and 20% the growth hypothesis. Given that nearly 60% of the specific countries surveyed provide support the neutrality or conservation hypotheses indicates that energy conservation measures that reduce renewable energy consumption may not have an adverse effect on economic growth.

In addition to the studies reported in Table 4 on the causal links among renewable energy consumption and economic growth, there are some other renewable-growth nexus studies, such as those of Bowden and Payne [15], Ocal and Aslan [58], and Pao and Fu [63], which employ different techniques and examine the different aspects of nuclear-growth nexus. These studies are summarized below.

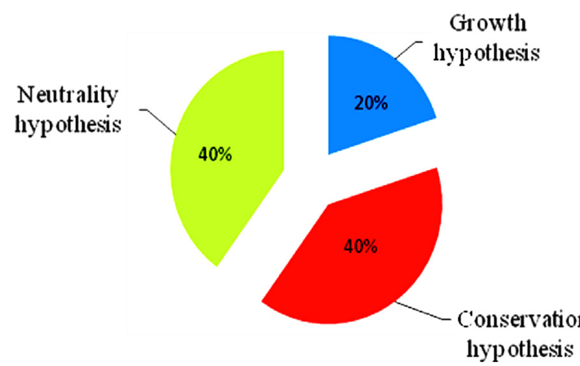


Fig. 4. Hypotheses for renewable-growth nexus (in %).

Bowden and Payne [15] examine the causal relationship between renewable and non-renewable energy consumption by sector and real Gross Domestic Product (GDP) in the United States using annual data from 1949 to 2006. The Toda–Yamamoto long-run causality tests reveal the absence of Granger-causality between commercial and industrial renewable energy consumption and real GDP, respectively. Bidirectional Granger-causality exists between commercial and residential non-renewable energy consumption and economic growth, respectively. Finally, the results indicate a unidirectional causality from residential renewable energy consumption and industrial non-renewable energy consumption, respectively to real GDP. More recently, Ocal and Aslan [58] have investigated the economic growth-renewable energy consumption causality relationship in Turkey using data from 1990 to 2010. The results of country-specific study support the evidence of the conservation hypothesis. The empirical evidence from the ARDL bounds test show that renewable consumption has a negative effect on economic growth. In contrast, a unidirectional causal relationship running from economic growth to renewable energy consumption is showed by Toda–Yamamoto tests. Pao and Fu [63] employ Brazil's yearly statistics from 1980 to 2010 to examine the causal relationship between real GDP and four types of energy consumption: non-hydroelectric renewable energy consumption (NHREC), total renewable energy consumption (TREC), non-renewable energy consumption (NREC), and total primary energy consumption (TEC). The cointegration test reveals a long-run equilibrium between Brazil's real GDP, labor, capital, and each of the four types of consumption. The development of the Brazilian economy has close ties with capital formation and labor force. The influence of NHREC/TREC on real output is positive and significant, while the impacts of NREC/TEC are insignificant. The results from the vector error correction models reveal the unidirectional causality from NHREC to economic growth, a bidirectional causality between economic growth

and TREC, and the unidirectional causality from economic growth to NREC or TEC without feedback in the long-run.

Overall results from the reviewed studies in this subsection show that the litearure on renewable consumption-growth nexus produced inconclusive results and their is no consensus neither on the existence nor on the direction of causality among renewable energy consumption and economic growth.

3. Concluding remarks

The objective of this study is to survey the literature dealing with the causality between economic growth and four types of energy consumption (total energy consumption, electricity consumption, nuclear consumption, and renewable consumption) to suggest some policy implications for the futures studies. In addition, this survey gives researchers a 'snap shot' of the literature on the causality between energy/electricity/nuclear/renewable consumption and economic growth for country-specific studies. Understanding the causal links between economic growth and different types of energy consumption provides a basis for discussion in order to design and implementating effective energy and environmental policies. The general conclusion that we can raise from these studies is that there is no consensus either on the existence or on the direction of causality between these variable in the literature. These conflicting results, in terms of the four hypotheses (growth, conservation, neutrality, and feedback), may be attribuated to the different data set, selected variables and countries, and econometric approaches which have been used.

Our review analysis indicates that 41%, 27% and 33% of studies support feedback hypothesis for electricity consumption-economic growth, energy consumption-economic growth nexus and renewable energy consumption-economic growth nexus. A 36%, 29%, 40% and 11% of studies confirm growth hypothesis is for electricity consumption-economic growth nexus, energy consumption-economic growth nexus, nuclear energy consumption-economic growth nexus and renewable energy consumption-economic growth nexus. This suggests to encourage energy supply policies for consistent supply of energy to boost economic activities and hence economic growth for long run. For India, consistent supply of nuclear energy should be encouraged to promote economic activity in both countries. This indicates that reductions in energy (nuclear) supply will retard economic growth and in results energy demand is reduced. A 20%, 60% and 22% of studies validate the existence of neutrality hypothesis for energy consumption-economic growth nexus, nuclear energy consumption-economic growth nexus and renewable energy consumption-economic growth. The conservation hypothesis is confirmed in energy consumption-economic growth (24%), electricity consumption-economic growth nexus (23%) and renewable energy consumption-economic growth (34%). It indicates that reduction energy supply will not retard economic growth as energy consumption plays minor role in promoting economic growth.

According to Ozturk [62], to avoid these conflicting results, the authors should focus more on the new methods and employ multivariate models rather than use usual methodologies based on a set of common variables for different countries or regions, different intervals of time to get more reliable and better results and understanding of economic growth-energy/electricity/nuclear/renewable consumption relationships [42]. Because papers using the same variables with the same methodology, just by changing the time periods, have no more potential to make a contribution to the existing literature on energy-growth nexus.

For further research, authors should use huge frequency data to investigate the relationship between energy (electricity, renewable and nuclear) consumption and economic growth. The results of the above stduies may be biased due to use of small sample size data. The assumptions of application of appropriate technique should be fulfilled. The developed and developing economies implement reforms such as macroeconomic, trade, financial, energy and environmental to sustain economic growth, develop financial sector, energy sector and improve environmental quality. These reforms affect energy consumption via stimulating economic activity and hence economic growth. This is required for application of cointegration for exmaining the long run in the presence of structural break in the series such as developed by [31]. The multiple structural break unit root test developed by Carrion-i-Silvestre et al. [16] is needed to test the integrating properties of the variables. There is specification bias found from the above studies while investigating the relationship between energy consumption and economic growth. These potential variables are governance, political insituions quality, political instability, foreign capital inflows, income inequality, devaluation and environmental taxation which not only affect energy demand but also environmental degradation in developed and developing economies of the globe. Similarly, the use of data on per capita electricity consumption, for example, or per capita real income to delineate similarities and differences between countries using panel error correction modeling, which provide additional insights on the impact of electricity consumption within the stages of economic development.

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